Development of Micromachines Using Deep X-Ray Lithography

Ming X. Tan

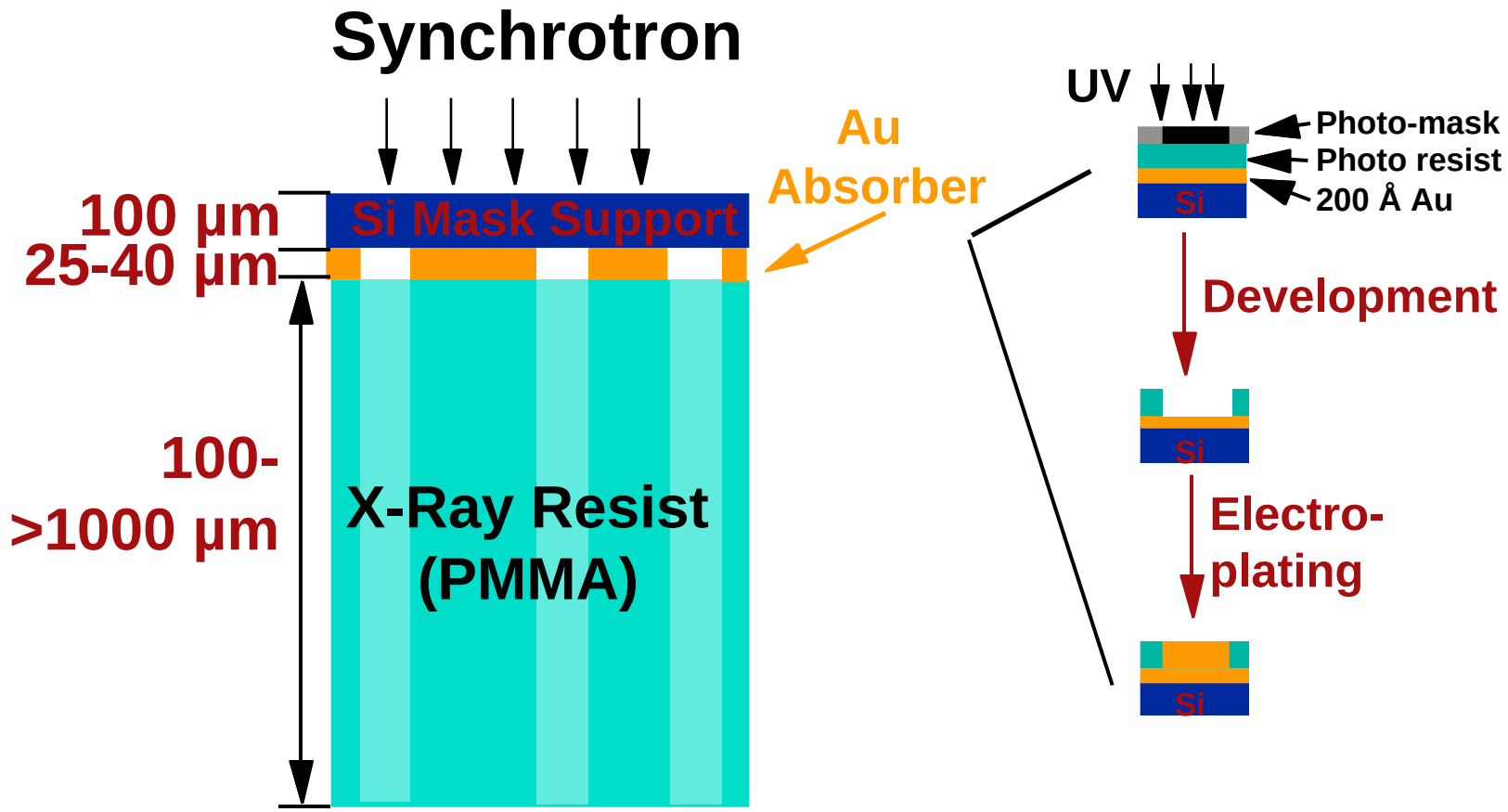
Outline

- **Background of LIGA process.**
- **Examples of LIGA fabricated micromachine parts.**
- **Material studies in LIGA:**
  - **Research on the development of PMMA resists**

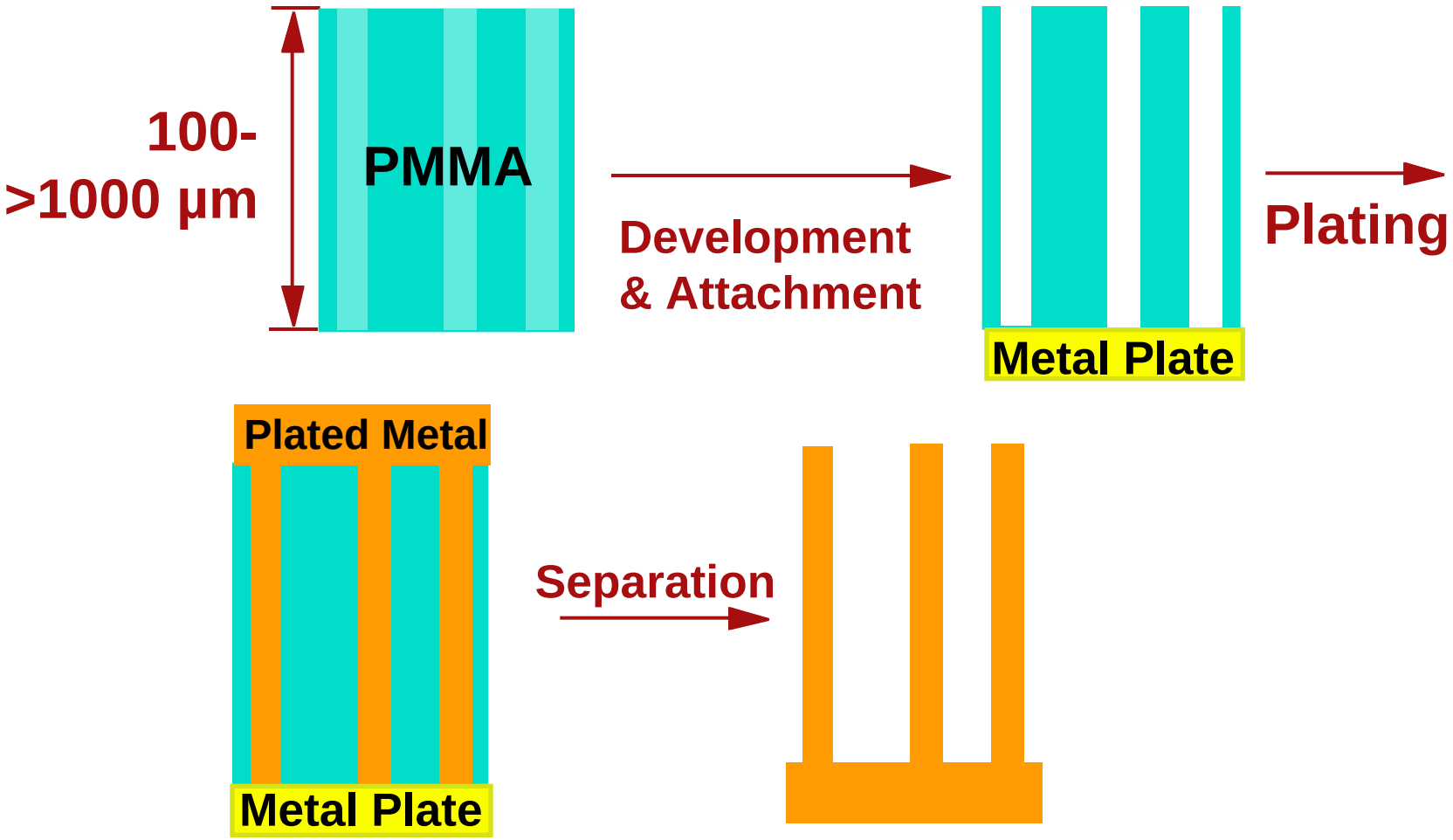
LIGA

(Lithographie, Galvanoformung, Abformung)

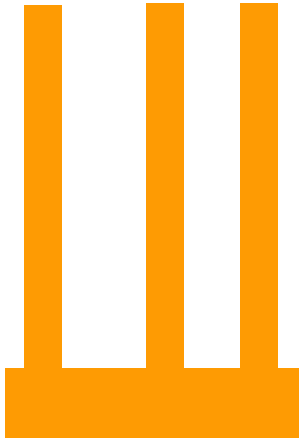
(Deep x-ray lithography, electroplating, molding)



Development and Electroplating

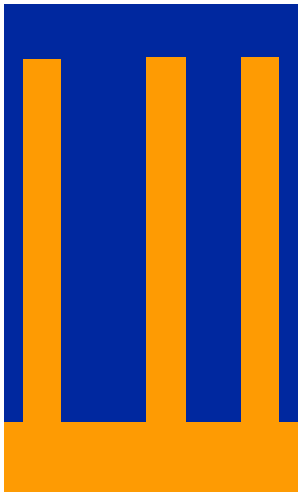


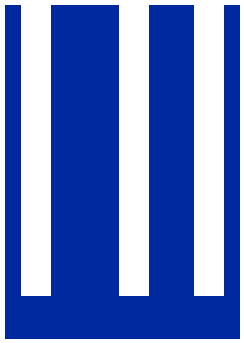
Molding



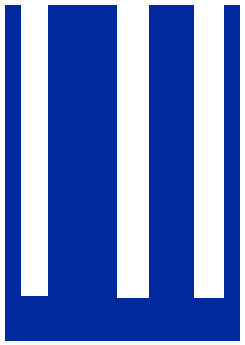
Injection Molding

or Metal Plating

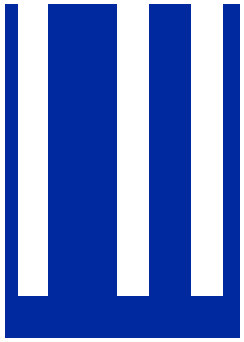




Plastic



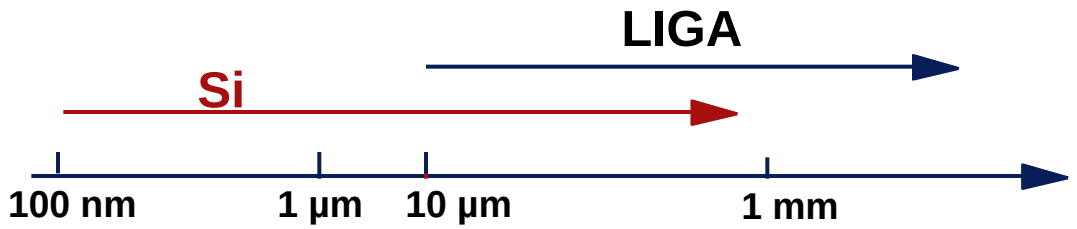
Ceramic



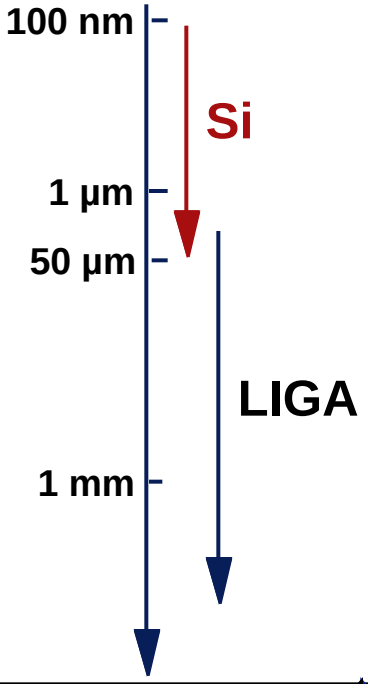
Metal Alloy

LIGA vs. Si micro-lithography

Surface Dimension



Vertical Depth



Vertical Slope

< 1µm/mm

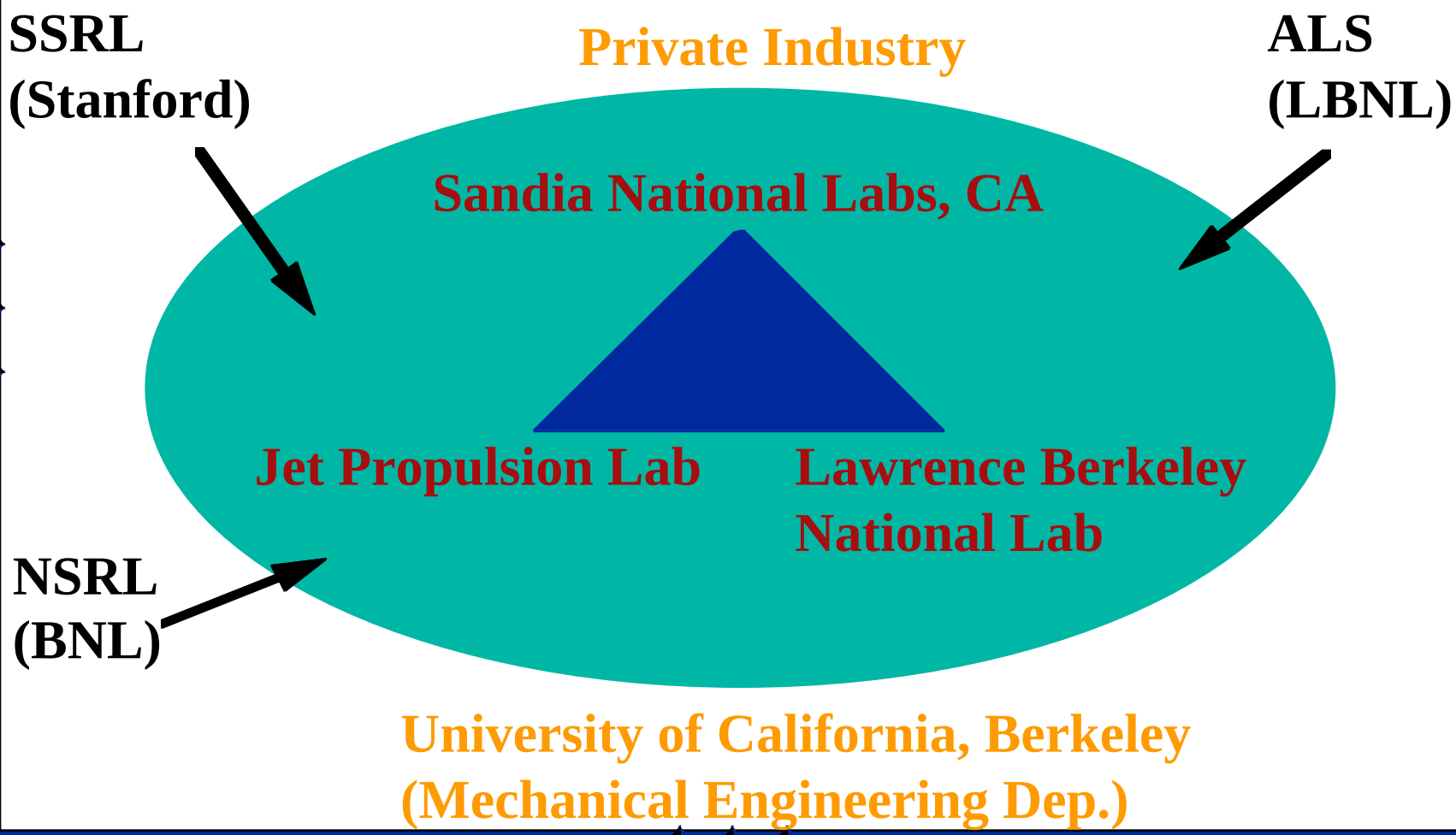
LIGA Advantages

- **Provides unique dimensions for microdevices:**
- **Fabricates devices of various materials:**
  - **Metal, alloy metal**
  - **Polymers, bio-compatible polymers**
  - **Resins with special optical properties**
  - **High temperature ceramics**
- **Molding process provides possibility of simple mass production.**

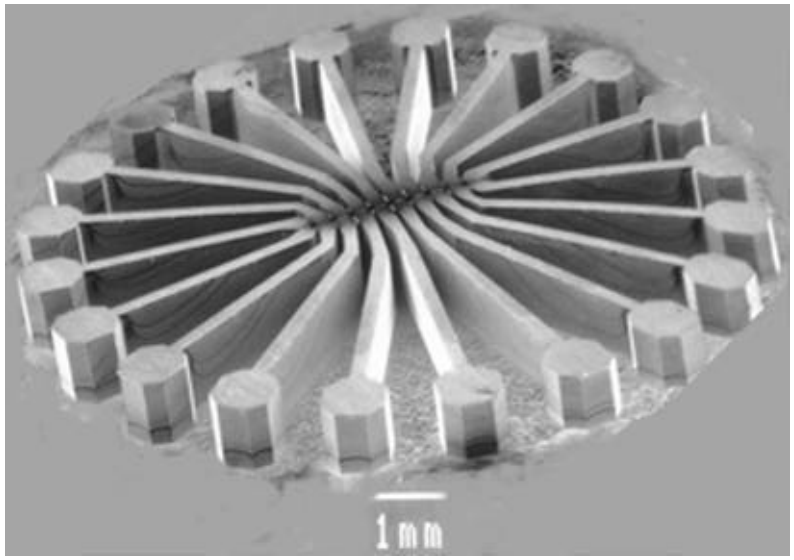
Limits

- **Assembly**

LIGA Activities in California



LIGA Applications - Chemical Sensor Miniaturization

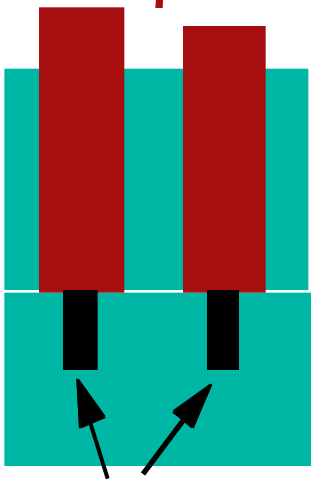


Mass Spectrometer (JPL/SNL), for 1-300 AMU detection.

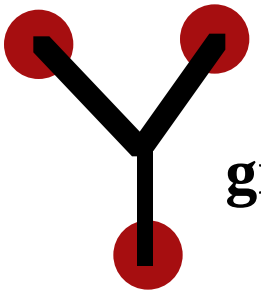
Micro Electrochromatography (SNL), 360 µm capillary tube in a 360 ± 1.5 µm hole, 2.3 mm deep.

Micro Electrochromatography

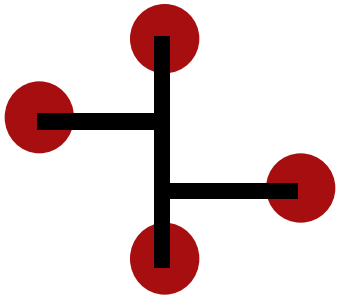
Micro-capillary tubes
O.D. = 360 μm
I.D. = 78 μm



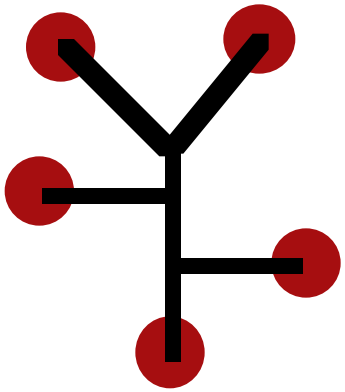
Micro-channel
W= 78 μm
H = 80 μm



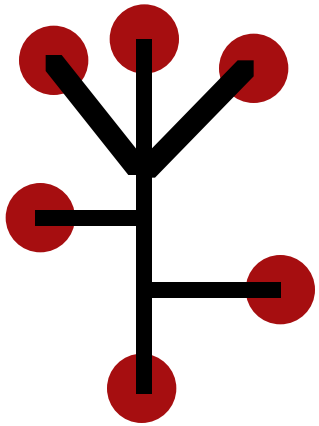
gradient



injection

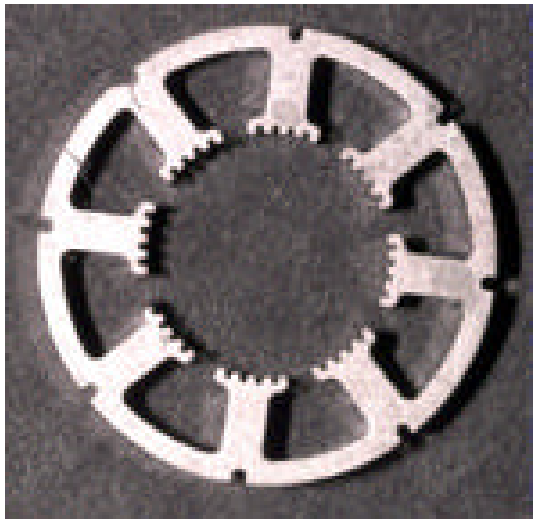


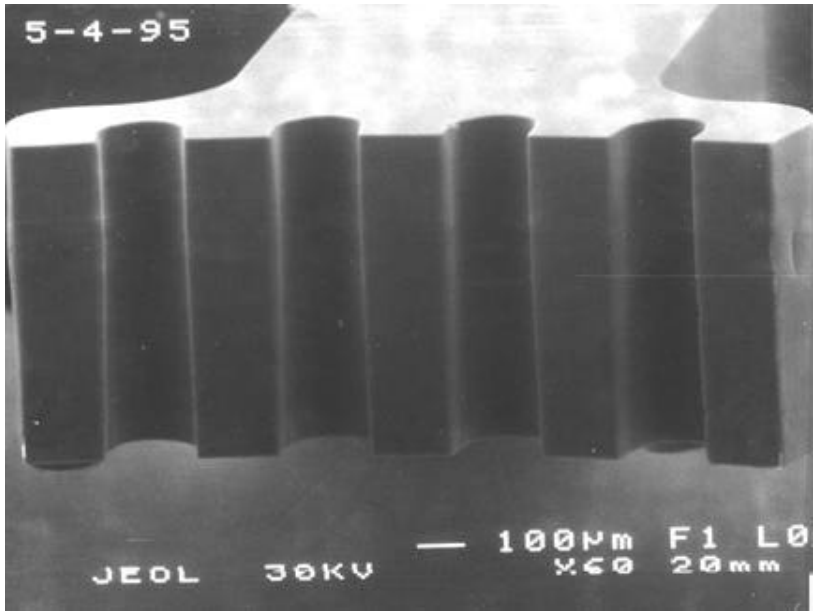
gradient+injection



reaction + injection

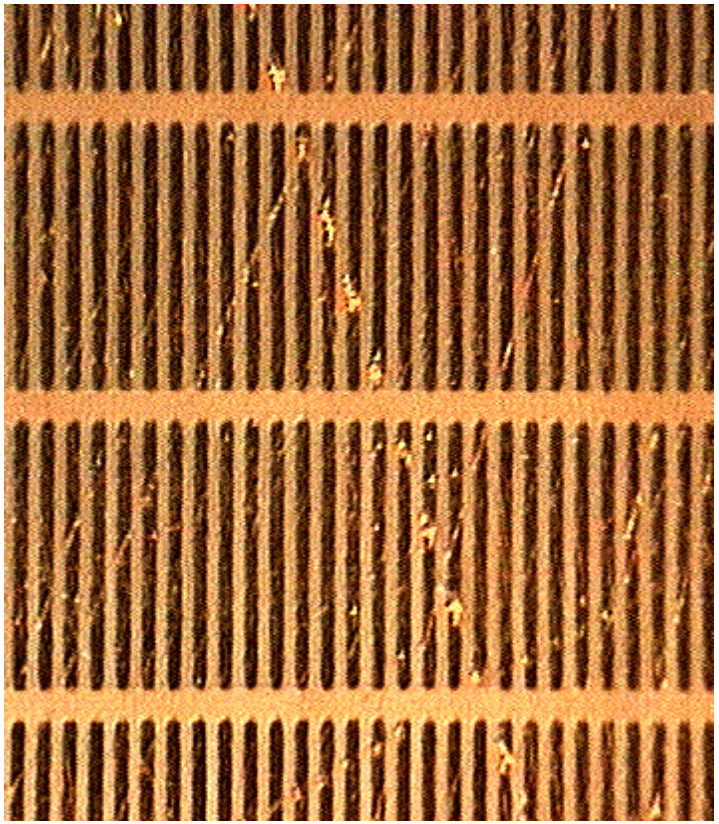
LIGA Applications - Actuators

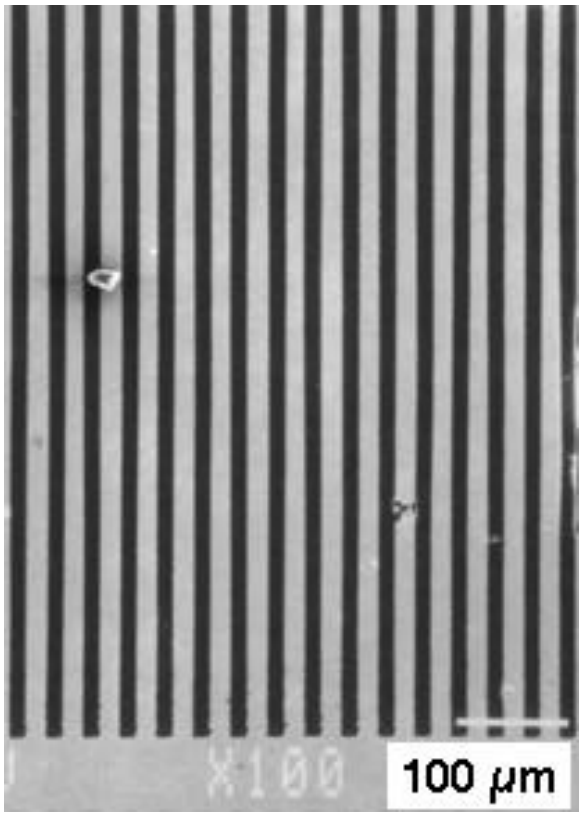




Size 5 Stepper - Stator (LBNL/SNL)
Step Size 1.8 Degree, Ni/Fe Alloy
Requires very vertical side wall and high precision

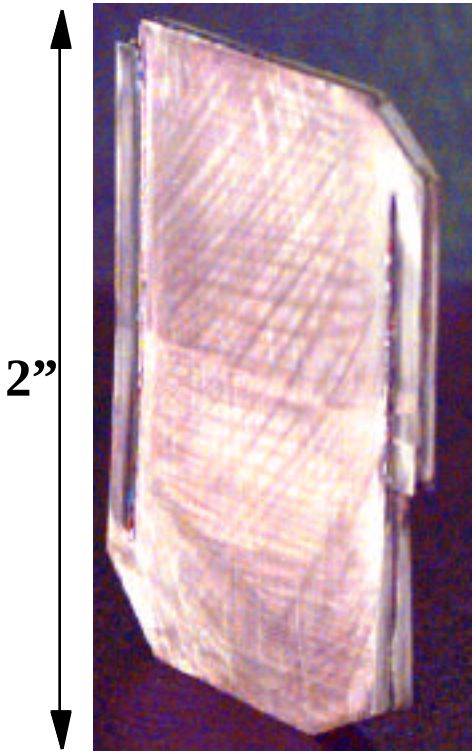
LIGA Applications - High Precision Micro Devices

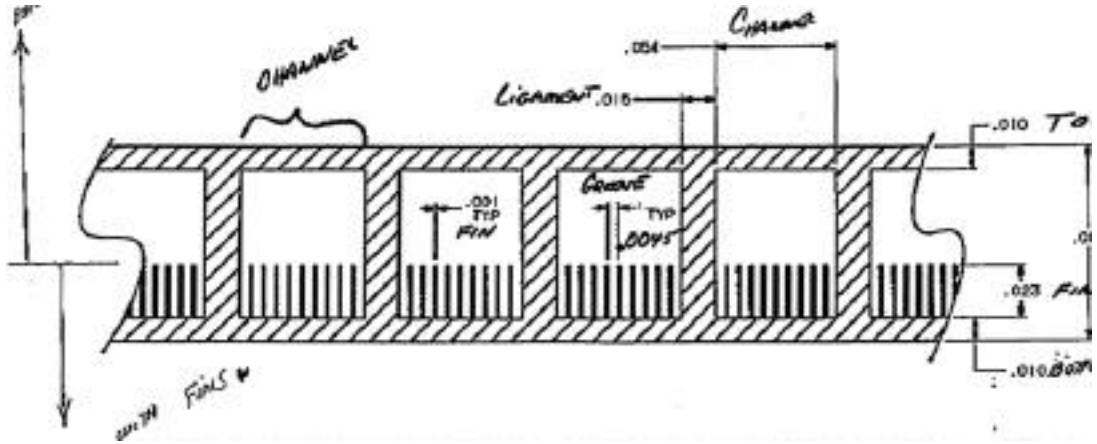


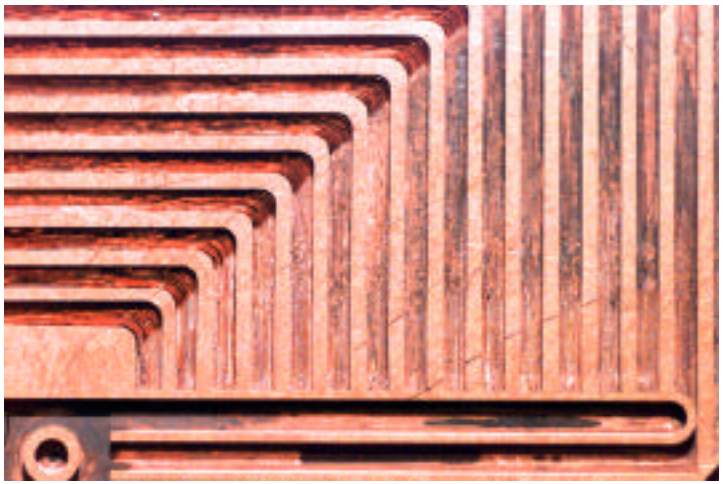


Solar Grid (JPL/SNL), 16 µm wide, 1mm tall gold grids.

Lockheed Martin/SNL Heat Pipe



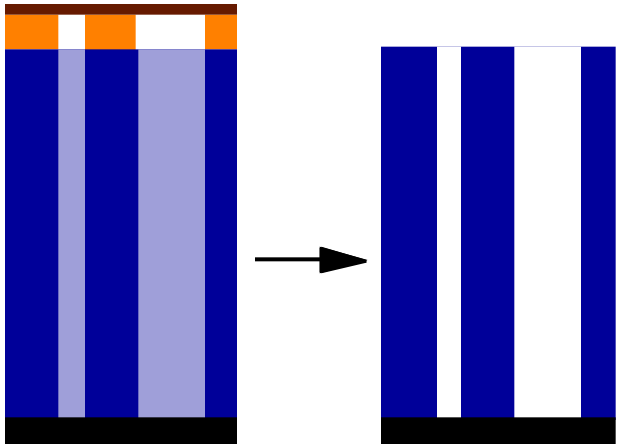




Material Issues in LIGA Fabrication

- **LIGA mask fabrication;**
- **PMMA development as functions of exposure;**
- **PMMA attachment to metals;**
- **Plating in high aspect ratio deep channels, plating of different metals and alloys;**
- **Molding;**
- **Material characterization, tolerance, mechanical property measurements.**

What Controls Development Rate ?

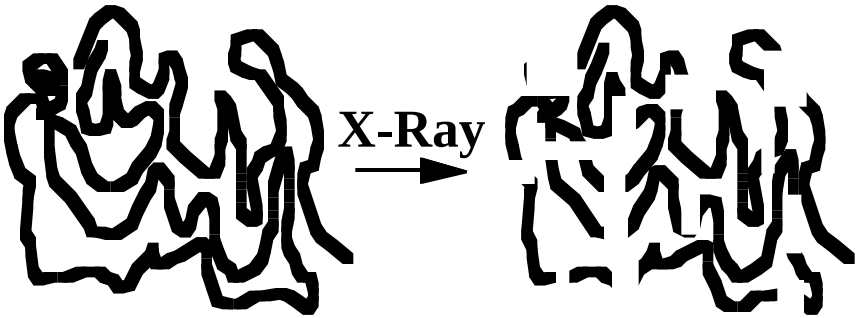


Exposure Development

Development Rate
PMMA Chain Length
Exposure Dose

Some Other Factors:

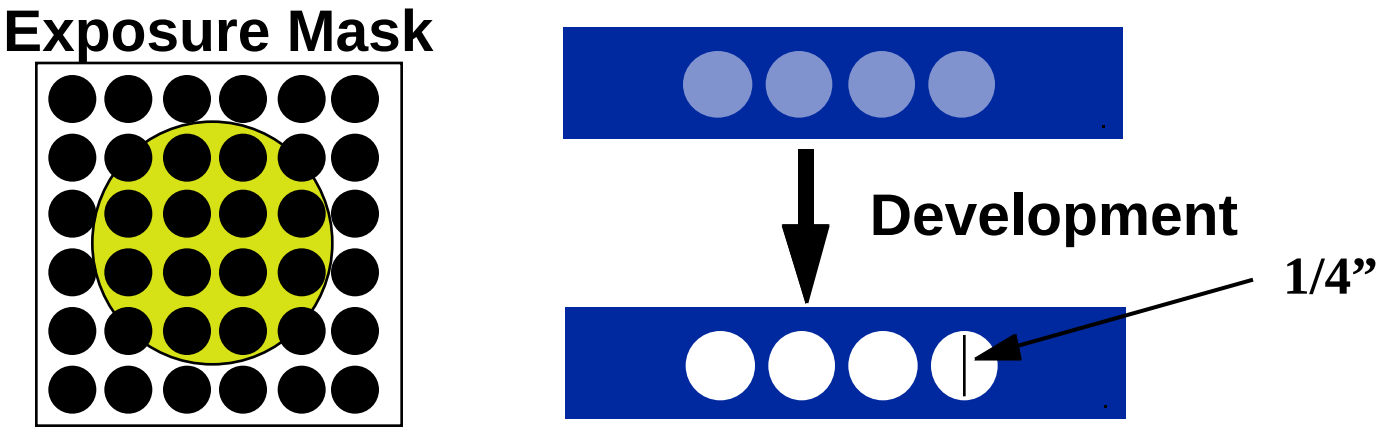
- PMMA properties
- Dev. Temp.
- Exp. Condition
- Pre-treatment

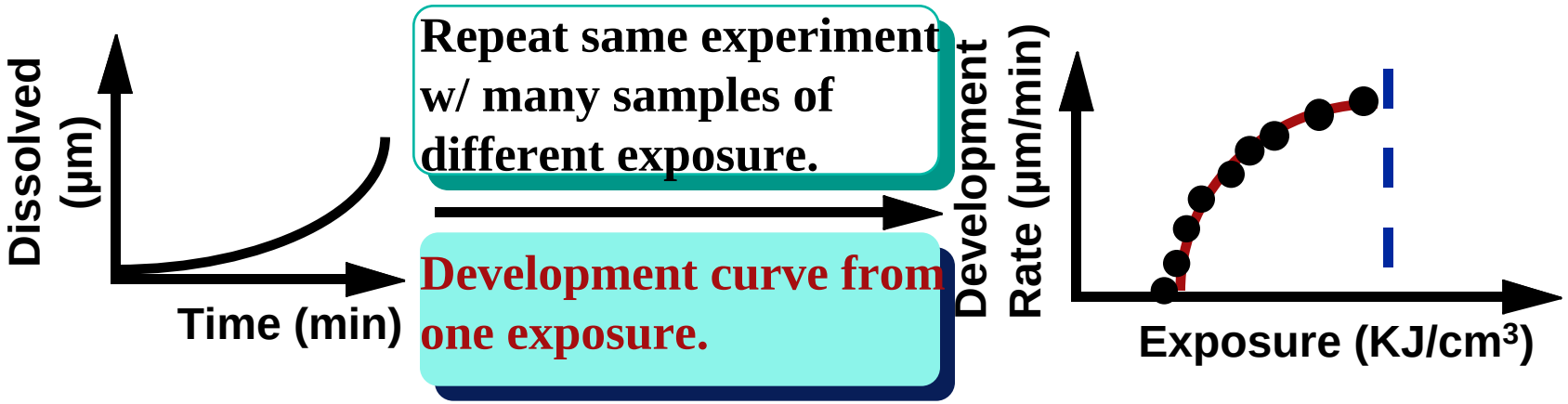


Unexposed PMMA

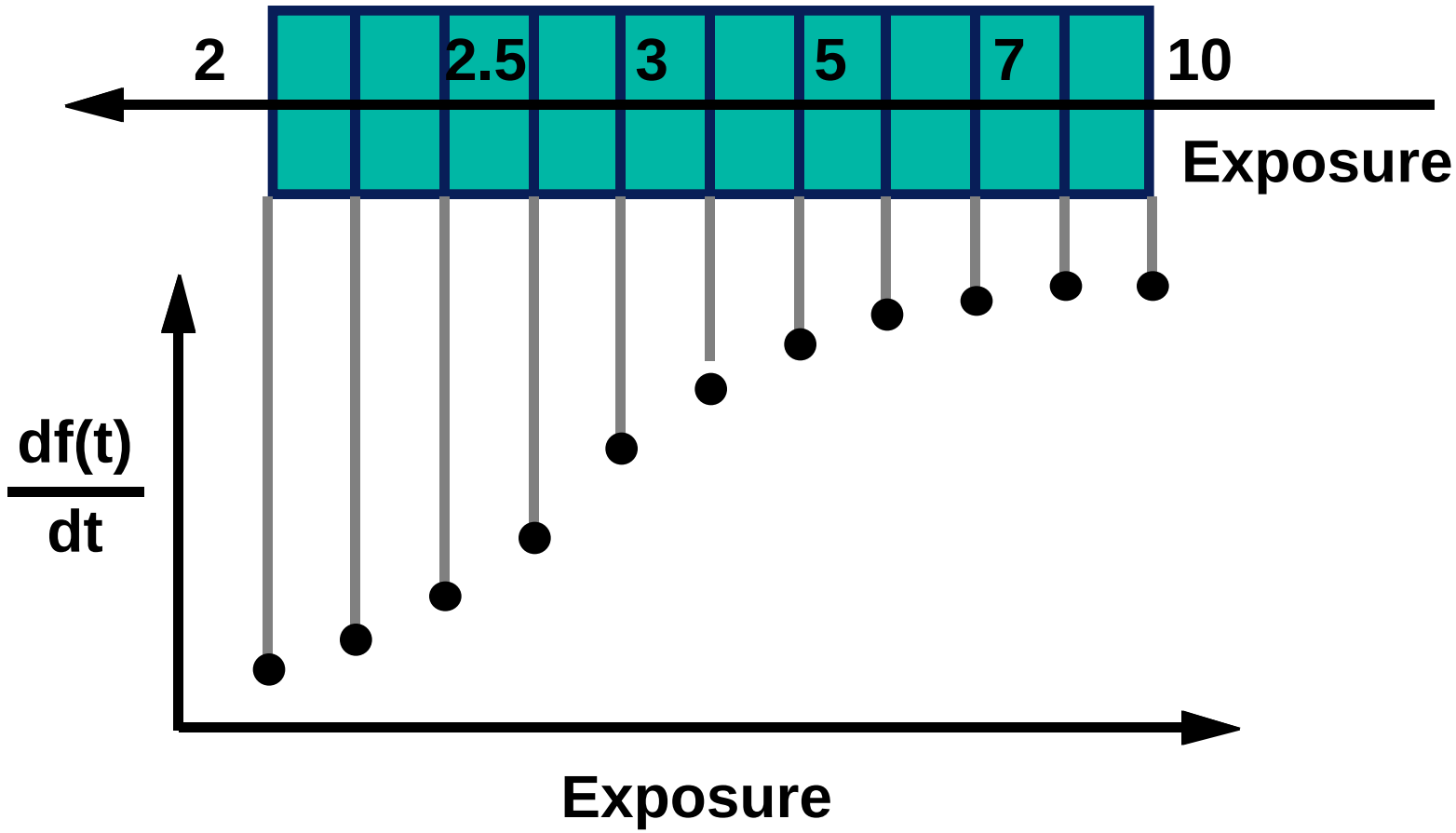
Exposed PMMA

Approach to Produce Development Curves



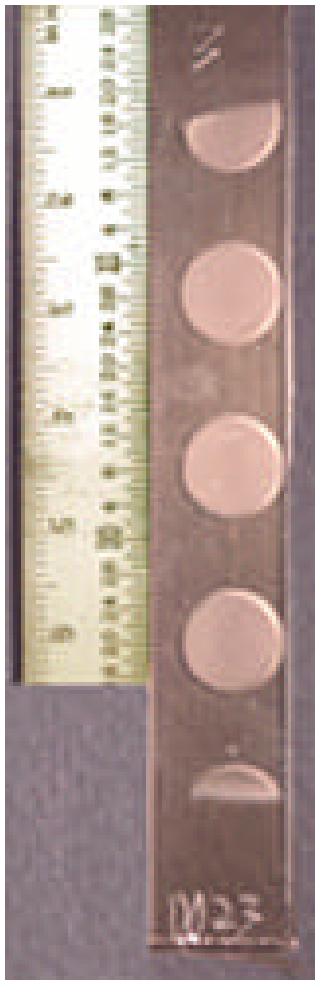


Development Curve From One Exposure

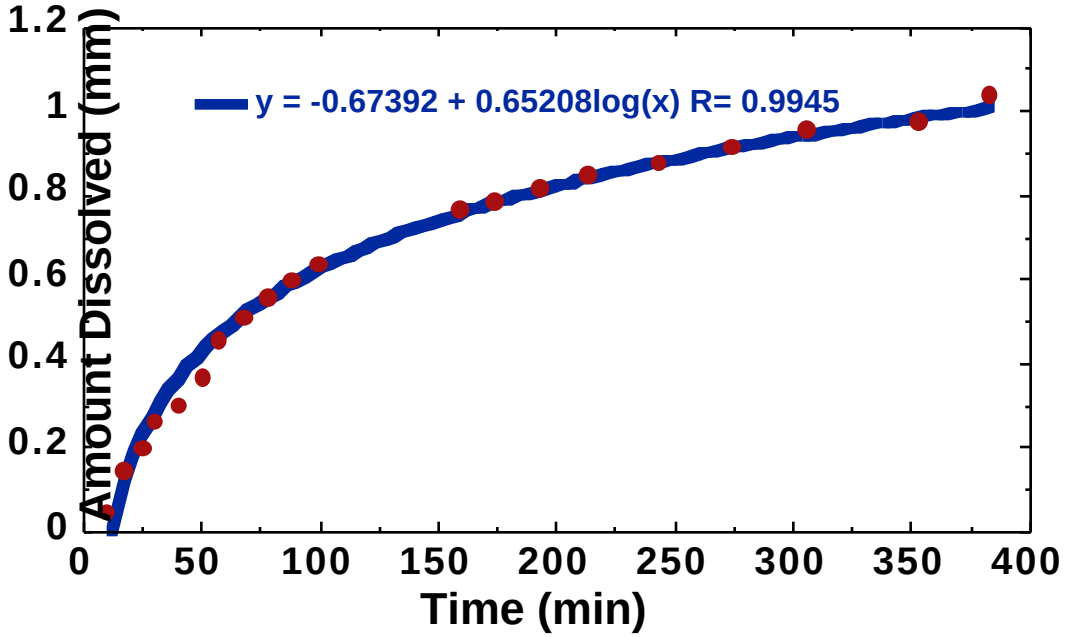


f(t) - Thickness of PMMA dissolved with time

Experimental Set-up



PMMA Dissolved Thickness vs. Time

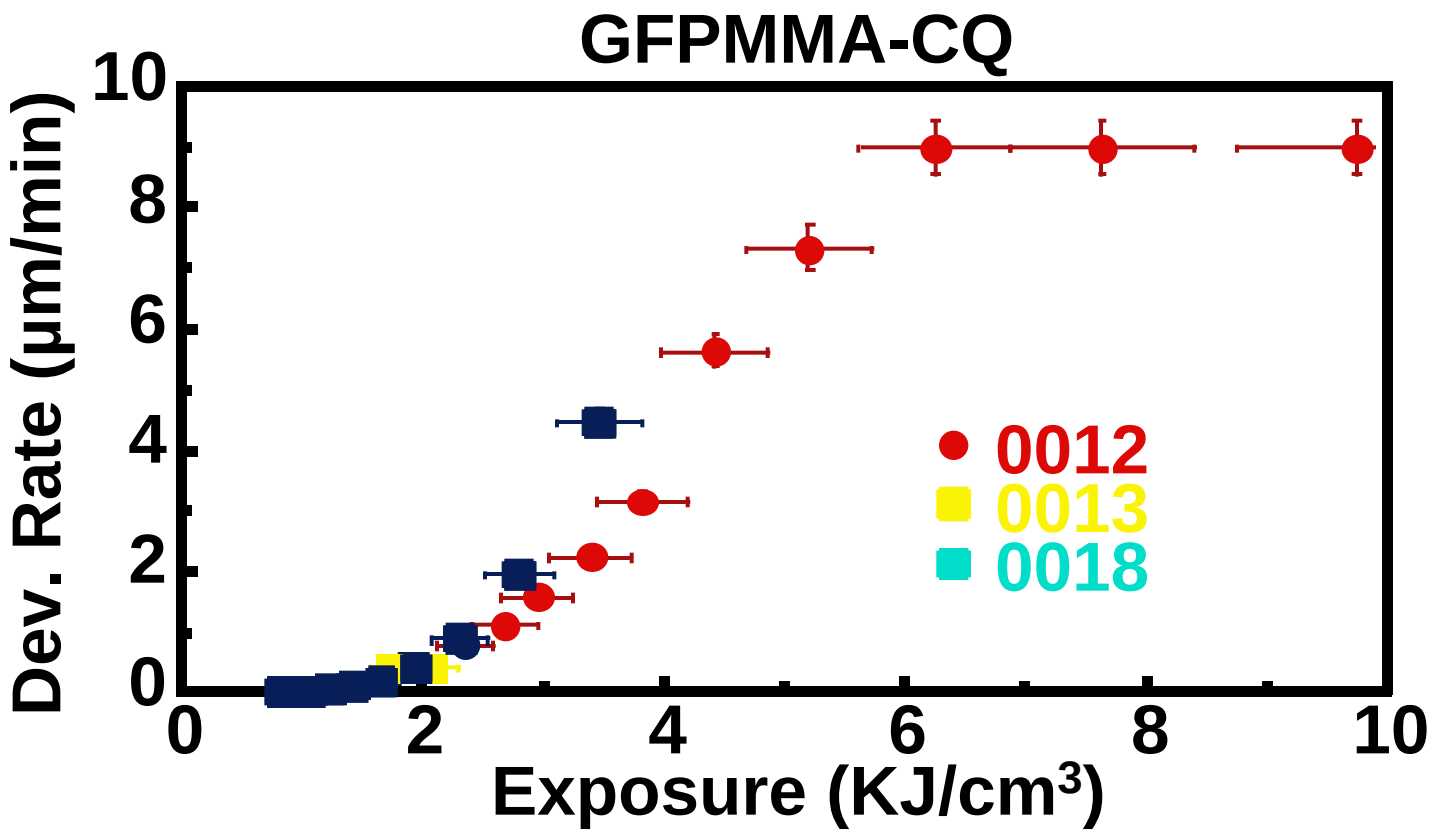


Dissolved = f(t) = -a + blog(t)

df/dt = blog(e)/t

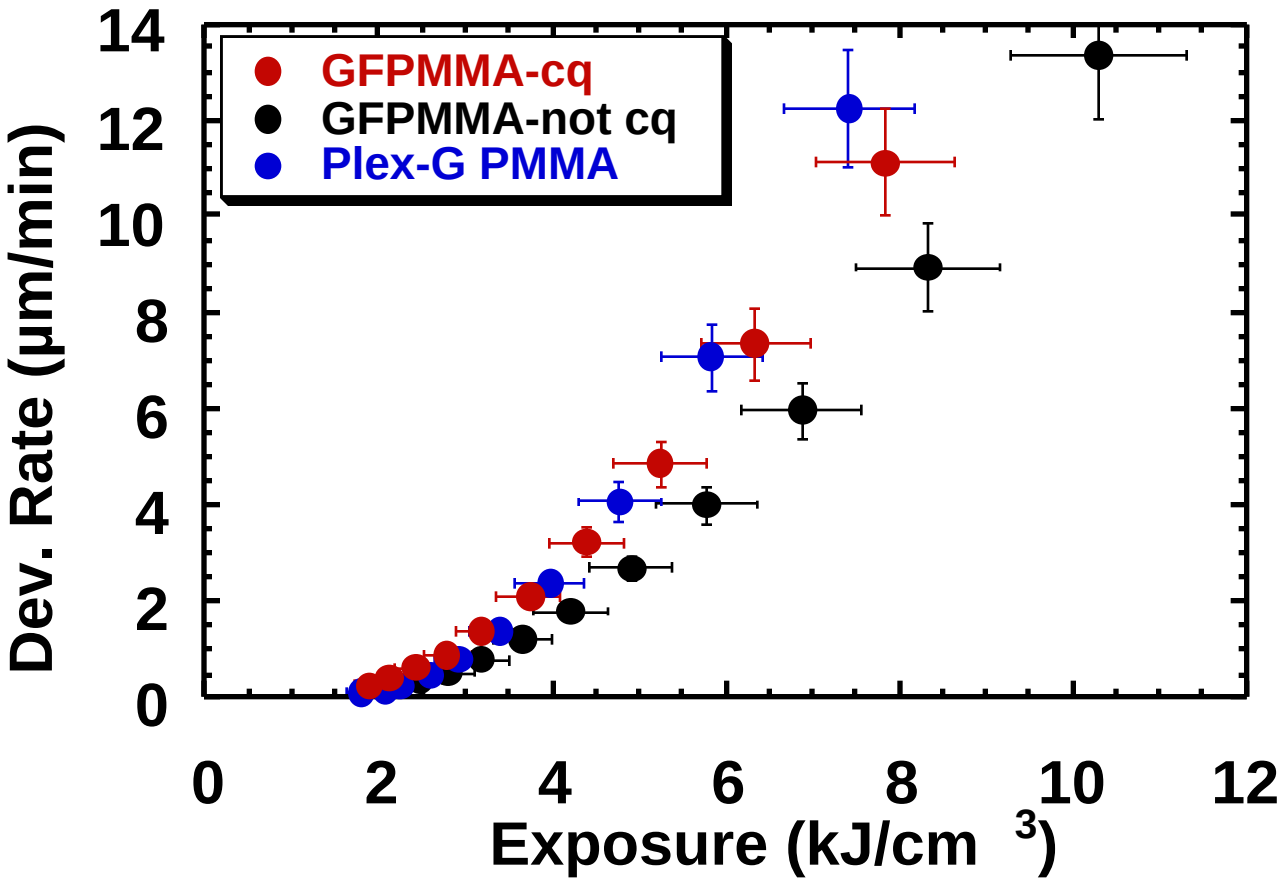
Development Rate(f) = blog(e)/[$10^{(f+a)/b}$]

Development Curves from 3 Exposures



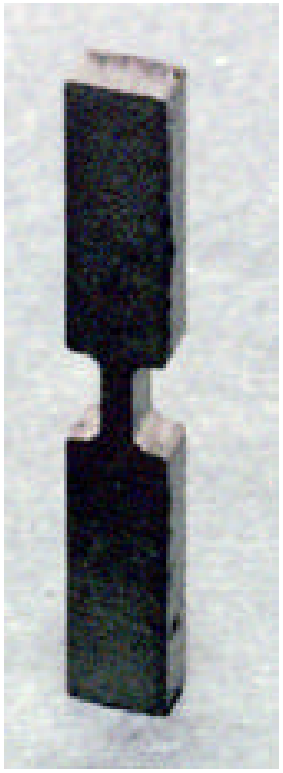
Development curve can be obtained with single exposure.

Development Rate vs. Polymer Property



GFPMMA-cq has similar development curve as Plex-G.

LIGA Material Characterization



SNL Compression/Tensile Testing Parts
600 µm wide (middle), 1mm thick

SNL/UCB/LBNL Tolerance Test

Testing:
Roundness
Angularity
Concentricity
Dimensional Accuracy
Aspect Ratio

Summary

- We have made many advances in LIGA material and process development, such as PMMA development, plating, etc.
- Through collaborations with UCB, LBNL, JPL, we have successfully fabricated micromachine parts for a variety of applications.

Acknowledgment

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